Stratification of Soil Organic Matter and its Potential Impact on Environmental Quality

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Rationale

Soil organic matter is a key component of soil quality, sustaining many vital soil functions by providing the energy, substrates, and biological diversity to support biological activity, important for:

aggregation; important for habitat space, O_2 supply, and preventing soil erosion
infiltration; important for leaching, runoff, and water uptake
decomposition; important for nutrient cycling and detoxification of amendments

Lack of residue cover and exposure of soil to high-intensity rainfall can result in poor aggregation, reduced plant water availability, erosion, and off-site impacts of sedimentation and poor water quality.

It is hypothesized that the degree of soil organic matter stratification could indicate soil quality or ecosystem functioning.

However, there is growing concern that continual fertilizer or manure application to pasture or conservation-tilled soils might lead to deterioration of surface water quality from the accumulation of P at the soil surface (Sharpley, 2003; Pote et al., 2006).

Objective

Review available literature on how adoption of conservation management, which often leads to stratification of soil organic C, affects:
(1) water runoff volume and quality
(2) sequestration of soil organic C

Notations

CT: conventional tillage
NT: no tillage

Literature

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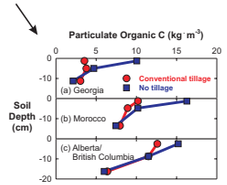
Tillage	Soil Loss (Mg/ha/yr) Mississippi	Georgia
Conventional	18	23
No tillage	3	<0.1

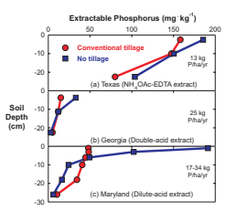
Data from McGregor et al. (1975) in MS, Endale et al. (2000) in GA

Stratification of Soil Organic Matter

Many soil organic matter fractions become stratified with depth, including total, particulate, microbial biomass, and mineralizable C and N (Franzluebbers, 2002a). Degree of stratification appears to depend upon the soil organic matter fraction, soil type, climatic conditions, time, and management.



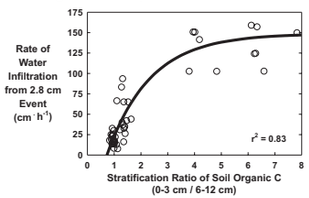
Data in Georgia from Franzluebbers et al. (1999), in Morocco from Mrabet et al. (2001), and in Alberta from Franzluebbers and Arshad (1997).



Data in Texas from Franzluebbers and Hons (1996), in Georgia from Hargrove et al. (1982), and in Maryland from Weil et al. (1988).

With continuous application of P fertilizer, stratification of soil P can occur in the soil profile, especially under conservation tillage. At present, the accumulation of total and labile soil P at the surface under conservation tillage is viewed as a threat to water quality from runoff (Sharpley, 2003).

Soil with a high degree of organic C stratification leads to rapid water infiltration from the absorbent surface layer that resists slaking and creation of extensive macropores from enhanced biological activity without disturbance (Franzluebbers, 2002b).



Water Runoff Volume and Quality

On small (1.4 m^2) runoff plots in Wisconsin under maize, extractable soil P was greater under NT than CT at the soil surface, yet runoff loss of P fractions was mitigated by the presence of surface residue and high surface organic C.

Tillage	Soil Organic C	Extractable Soil P	Phosphorus Loss in Runoff Total	Dissolved	Bioavailable
	Mg/ha	mg/kg	kg/ha/event		
Conventional	32.5	39	1.31	0.02	0.21
No tillage	38.3	62	0.18	0.01	0.03

Data from Andraski et al. (1985).

On runoff plots (112 m^2) in Virginia under wheat/soybean-maize, sediment and nutrient loss in runoff were greatly reduced with NT compared to CT. Dissolved N in runoff from NT was 50% of that from CT, but dissolved P in runoff from NT was 4 times greater than from CT. P loss with CT was 95% associated with sediment, while that with NT was 77% associated with the dissolved fraction.

Tillage	Runoff	Sediment	Nitrogen	Phosphorus
	mm	kg/ha		
Conventional	46	3558	10.3	4.1
No tillage	10	18	0.5	0.3

Data from Ross et al. (2001).

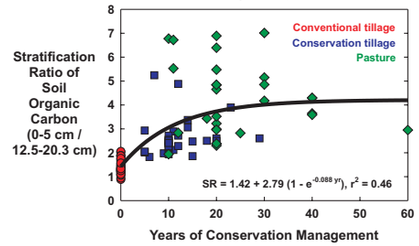
On paired watersheds (2.8 ± 0.8 ha), mean soil loss and total P in runoff were lower under NT than under CT. Runoff loss of bioavailable P tended to be greater under NT than under CT, suggesting that overland flow of water without sediment transport was still carrying dissolved nutrients.

Tillage	Runoff	Soil Loss	Phosphorus in Runoff Particulate	Bioavailable	Total
	%	Mg/ha	kg/ha/yr		
Bushland, Texas (54 cm rainfall)					
Stubble mulch	5	0.9	0.5	0.1	0.5
No tillage	8	0.5	0.3	0.2	0.4
Woodward, Oklahoma (60 cm rainfall)					
Disk tillage	17	39.6	14.4	0.9	14.9
No tillage	23	1.9	1.8	1.5	2.9
El Reno, Oklahoma (74 cm rainfall)					
Plow tillage	20	12.8	5.7	1.2	5.9
No tillage	24	0.4	0.5	1.4	1.7

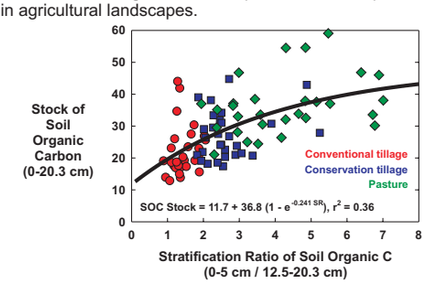
Data from Sharpley et al. (1992).

Soil Organic C Sequestration

In an on-farm survey of three primary land uses in five southeastern states (AL, GA, SC, NC, VA), soil organic C became increasingly stratified with years under conservation management (i.e., conservation tillage and pasture). The plateau was reached in about 20 years (Causarano et al., 2006).



The stock of soil organic C (SOC) to a depth of 20 cm was closely related to the stratification ratio of SOC from this on-farm survey of 87 fields. These data indicate that surface SOC was most dynamic in response to management, and that stratification ratio of SOC could be a soil-independent indicator of management consequences on C sequestration in agricultural landscapes.



Conclusions

- Soil with stratified depth distribution of organic matter has enhanced water infiltration.
- Soils under long-term conservation management have high surface organic matter and reduced water runoff volume and sediment transport.
- Unfortunately, too few water quality studies have data reporting soil organic matter and its stratification with depth, which could be a key indicator linking soil and water quality.
- Total loss of nutrients is often reduced with conservation tillage, because of a reduction in sediment-borne nutrients.
- Bioavailable P in water runoff may be a threat to water quality, although multi-season and multi-year data describing field-scale management impacts on water runoff characteristics are needed.
- High stratification ratio of soil organic C is indicative of enhanced soil organic C sequestration.
- Interaction of nutrients with surface residue and soil organic matter may be complex, but could be the key to developing sustainable soil management systems.